Letter and enclosure to Alexander Graham Bell, December 9, 1909

Beinn Bhreagh, near Baddeck , Nova Scotia . December 9, 1909. Dr. Alexander Graham Bell, Washington, D. C. Dear Mr. Bell:

We have been so busy getting the machine ready to show His Excellency a jump that I really haven't had a moment before this to correct what I said about high-flying.

All that I said about resistance is perfectly true, but we overlooked the time element in considering the power which would be required to support a machine at higher velocities in less dense air.

Horse power is the rate of doing work and work is the product of force multiplie d by distance through which it acts. If you raise one pound two feet in a second you do twice as much work per second as if you raised it one foot per in a second. This is exactly similar to the case of maintaining the thrust on a propeller at different speeds. The resistance of the machine at twice the velocity in air of one-half the density would be the same; but the difficulty lies in maintaining the thrust at twice the speed so that what we really have is this.

The speed of the machine must be inversely proportional to the density of the air if it is to support itself, and the power necessary to maintain this speed directly proportional to the speed.

Thus in the case we have. A forty mile an hour 2 machine developing 40 H.P. would require 80 H.P. to maintain flight at an elevation of 16000 feet. The resistance of the machine at 80 miles an hour at this elevation would be the same as at 40 miles an hour near the ground; so it seems that a heavier-than-air machine will have its limits as to elevation just as in the case of a dirigible balloon.

The principle of high-flying is, however, perfectly correct. By this means only can we get a machine which will not increase its resistance at higher velocities. The most perfect reefing aerodrome cannot achieve this at low elevations because some parts (the non-supporting portions of the machine) are un-reefable.

It is doubtful if a dirigible balloon can take advantage of the less dense air at higher elevations. If it flies high it must displace more air and consequently offer substantially the same resistance. At any elevation this resistance will increase as the square of the velocity and the power necessary to drive it as the cube of the velocity. Thus a 40 mph dirigible would have a resistance four times as great at 80 miles an hour and require eight times as much power; so that it would require four times as much power to double the speed as in the case of the aerodrome.

In the case of the heavier-than-air machine flying at a constant elevation the resistance will also increase as the square of the velocity; but as the lift developed follows the same law, the angle of attack can be reduced. As this, however, will only decrease one element of the resistance it is clear that the greater part of the resistance

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Hydro Curve Experiments.

Oct 27: — The towing experiments made with the Query give a most satisfactory proof of the theory that the resistance of a reefing hydro-surface does not increase with the speed.

In the case of the submerged hydro-surface the weight supported, and the resistance both increase as the square of the velocity. That is, the lift and drift preserve a constant ratio and both vary as the square of the velocity.

If the hydro-surface is only called upon to support a constant load (viz., the weight of the hull) and is so arranged that it will automatically reef itself, then it is clear that the area decreases as the square of the velocity, and the drift or resistance remains constant. To illustrate:—

Let W = weight supported

A = area of hydro-surface

R = resistance

L = lift of hydro-surfaces

D = drift of hydro-surfaces

at supporting velocity W = L

at supporting velocity R = D

Now lift is proportional to square of velocity.

Also the drift or resistance is proportional to square of velocity.

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The resistance is therefore equal the weight supported multiplied by [???] which is a constant representing the efficiency of the hydro-surfaces and is independent of the velocity.

To obtain conditions under which the resistance shall be independent of the velocity in practice where W is fixed and equal to the weight of hull it is only necessary to have A decrease with the square of the velocity.

Therefore if the hydro-surface arrangement has the ability to reef the resistance will be independent of the velocity. Example Suppose 1 sq. ft. of hydro-surface supports 100 lbs. at 10 miles per hr with of at 10 lbs. At 20 mph 100 lbs will be supported on ¼ sq. ft. and the resistance will still be 10 lbs.

The resistance curves made by Mr. Bell from the towing experiments clearly show that this is the case, and that we have all the elements of a high speed machine in an arrangement like the Query.

The comparison between the Query with and without hydro-surfaces as shown in photographs on pp is particularly interesting. It shows the advantage of hydro-surfaces above the critical speed where the curves cross at (about 15 mph.)

The drop in the resistance without hydro-surfaces below the general curve above at about 15 miles per hour probably indicates that the hull itself was giving some hydroplane action. FWB.